Check for updates

Measurement of Cervical Sagittal Alignment Parameters on X-Ray Films of Adults without Severe Spinal Deformity Whose Shoulder Hides the Lower Cervical Column

Hitoshi Yamahata[1], Jun Sugata[1], Masanao Mori[1], Tadaaki Niiro[1], Masanori Yonenaga[1], Satoshi Yamaguchi[2], Takaaki Hiwatari[1], Tomohisa Okada[1], Kazunori Arita[1], Koji Yoshimoto[1]

■ OBJECTIVE: **The Cobb angle between the lower endplate of C2 and C7 (C2L—C7L angle) is a traditional parameter used for the assessment of the cervical alignment. However, when the lower cervical column is masked by the shoulder, measurements are difficult. In the present study, we inspected 191 X-ray films, measured the Cobb angle between C2L and the endplates at the several levels of the lower cervical column, and assessed their usefulness of such measurements for the determination of cervical sagittal alignment.**

■ METHODS: **We obtained X-ray films on 191 patients ranging in age from 20 to 93 years. The Cobb angle between C2L and the C7 upper (C7U), the C6 lower (C6L), the C6 upper (C6U), and the C5 lower endplate (C5L) was measured and compared with the C2L-C7L angle.**

■ RESULTS: **C7L was identified in 116 of 191 patients (60.7%). Except for C2L-C7U angle ($P = 0.55$), the difference in the mean between C2L-C7L angle and the angle between C2L and the other endplates was statistically significant ($P < 0.05$). There was a very strong correlation between C2L-C7L angle and C2L-C7U angle ($r = 0.99$), C2L-C6L angle ($r = 0.96$), C2L-C6U angle ($r = 0.94$), and C2L-C5L angle ($r = 0.86$).**

■ CONCLUSIONS: **To measure the C2L-C7L angle on unclear X-ray films, C7U can be substituted for C7L. Our measurement data for the C6 and C5 endplates were statistically different; however, the correlation between the C2L-C7L angle and C2L-C6U angle, C2L-C6L angle or C2L-C5L angle was very strong. In patients with unclear lower vertebral bodies, cervical sagittal alignment can be predicted by using adjacent endplates.**

INTRODUCTION

Sagittal alignment plays an important role in spinal pathophysiology, and cervical sagittal alignment affects the maintenance of the global sagittal balance.[1-8] As the natural curvature of the cervical spine is lordotic,[7] loss of lordosis by, or kyphotic alignment of, the cervical spine contributes to the development of myelopathy.[9] Consequently, maintaining the physiologic sagittal alignment of the spine is essential for its long-term function. We compared sagittal alignment pre- and postoperatively to evaluate the treatment outcome.

Among parameters used for the assessment of sagittal cervical alignment,[1-5,7,8,10-12] the Cobb angle between the lower endplates of C2 and C7 (C2L-C7L angle) is a traditional parameter for the assessment of cervical lordosis.[12,13] When the lower cervical column is masked by the shoulder, PACS software is useful.[11] However, in individuals with a short neck or square shoulders, it can be difficult to observe the lower cervical column, especially in the flexion position.

Some reports on the assessment of cervical lordosis cited measurement difficulties when the X-ray films were unclear[4,6,10,14-17] and the divergence in inter- and intraobserver evaluations rendered the findings unreliable. In some instances, we replace the

Key words
- Cervical alignment
- Cobb angle
- Endplate
- Measurement

Abbreviations and Acronyms
C2L: C2 lower endplate
C2L-C7L angle: Cobb angle between C2L and C7L
C5L: C5 lower endplate
C6L: C6 lower endplate
C6U: C6 upper endplate
C7L: C7 lower endplate
C7U: C7 upper endplate
CT: Computed tomography
MRI: Magnetic resonance imaging
ROM: Range of motion

From the [1]Department of Neurosurgery, Graduate School of Medical and Dental Sciences, Kagoshima University, Kagoshima; and [2]Department of Neurosurgery, Hiroshima University Graduate School of Biomedical Sciences, Hiroshima, Japan

To whom correspondence should be addressed: Hitoshi Yamahata, M.D., Ph.D. [E-mail: yamahata-nsu@umin.net]

Citation: World Neurosurg. (2019) 121:e147-e153.
https://doi.org/10.1016/j.wneu.2018.09.051

*Journal homepage: **www.journals.elsevier.com/world-neurosurgery***

*Available online: **www.sciencedirect.com***

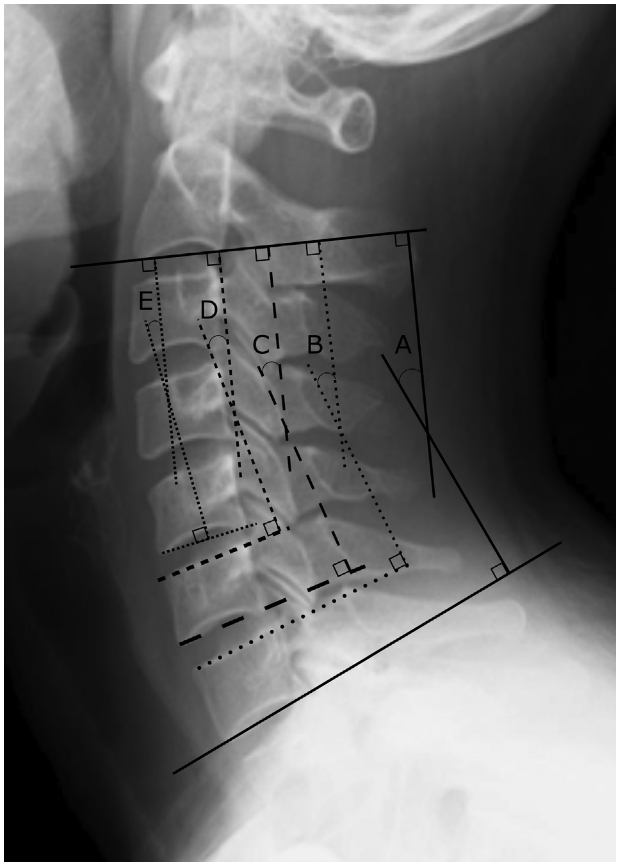

Figure 1. Measurements of the Cobb angle on X-ray images. (A) C2L-C7L angle, (B) C2-C7U angle, (C) C2L-C6L angle, (D) C2L-C6U angle, and (E) C2L-C5L angle.

unclear film with the adjacent endplate; however, the validity of this substitution remains to be established.

In the present study, we recorded the Cobb angle between C2L and endplates at several levels of the lower cervical column to assess whether the obtained measurement values were useful for determining the cervical sagittal alignment.

MATERIALS AND METHODS

The ethics committee of Kagoshima University approved this study. Included were 191 symptomatic and asymptomatic patients ranging in age from 20 to 93 years who underwent a checkup of the head or cervical region before cranial or spinal surgery or who were followed up postoperatively. They presented with 33 cranial (brain tumor, $n = 12$; cerebral infarction, $n = 6$; headache, $n = 5$; other, $n = 10$) and 158 spinal diseases (atlantoaxial subluxation, $n = 5$; cervical spinal canal stenosis, $n = 125$; spinal tumor, $n = 13$; spinal dural arteriovenous fistula, $n = 6$; other, $n = 9$). Excluded were patients whose subaxial cervical column endplates were unclear due to severe degenerative changes, patients who had undergone insertion of autologous bone grafts or spacers, and patients with severe spinal deformity.

All cervical lateral radiographs (neutral, flexion, extension) were obtained with the patient sitting on a stool with the arms hanging down loosely; the head was upright with horizontal gaze. The

Table 1. Visibility of the C7 Lower Endplate on Cervical X-ray Images

	Clear ($n = 116$)	Not Clear ($n = 75$)	*P* Value
Age, years	61.1 ± 13	62.1 ± 11	0.730
Sex, M/F	57/59	58/17	0.000
Asymptomatic/symptomatic	28/88	5/70	0.001

M, male; F, female.

Table 2. Measurement Results for the Cobb Angle Between the C2 Lower Endplate and Other Endplates in the Lower Cervical Column

Radiographic Parameter	Mean ± SD (°)	*P* Value
C2L-C7L angle	9.06 ± 14	—
C2L-C7U angle	7.98 ± 13	0.55*
C2L-C6L angle	4.34 ± 13	0.01*
C2L-C6U angle	4.74 ± 13	0.02*
C2L-C5L angle	2.31 ± 12	0.00*

SD, standard deviation; C2L, C2 lower endplate; C7L, C7 lower endplate; C7U, C7 upper endplate; C6L, C6 lower endplate; C6U, C6 upper endplate; C5L, C5 lower endplate.
*Unpaired Student *t* test compared with the value from C2L-7L angle.

Table 3. Correlation Coefficients for the Cobb Angle Between the C2 Lower Endplate and Other Endplates in the Lower Cervical Column

	C2L-C7L Angle
C2L-C7U angle	
r	0.99
P value	0.00
C2L-C6L angle	
r	0.96
P value	0.00
C2L-C6U angle	
r	0.94
P value	0.00
C2L-C5L angle	
r	0.86
P value	0.00

C2L, C2 lower endplate; C7L, C7 lower endplate; C7U, C7 upper endplate; C6L, C6 lower endplate; C6U, C6 upper endplate; C5L, C5 lower endplate.

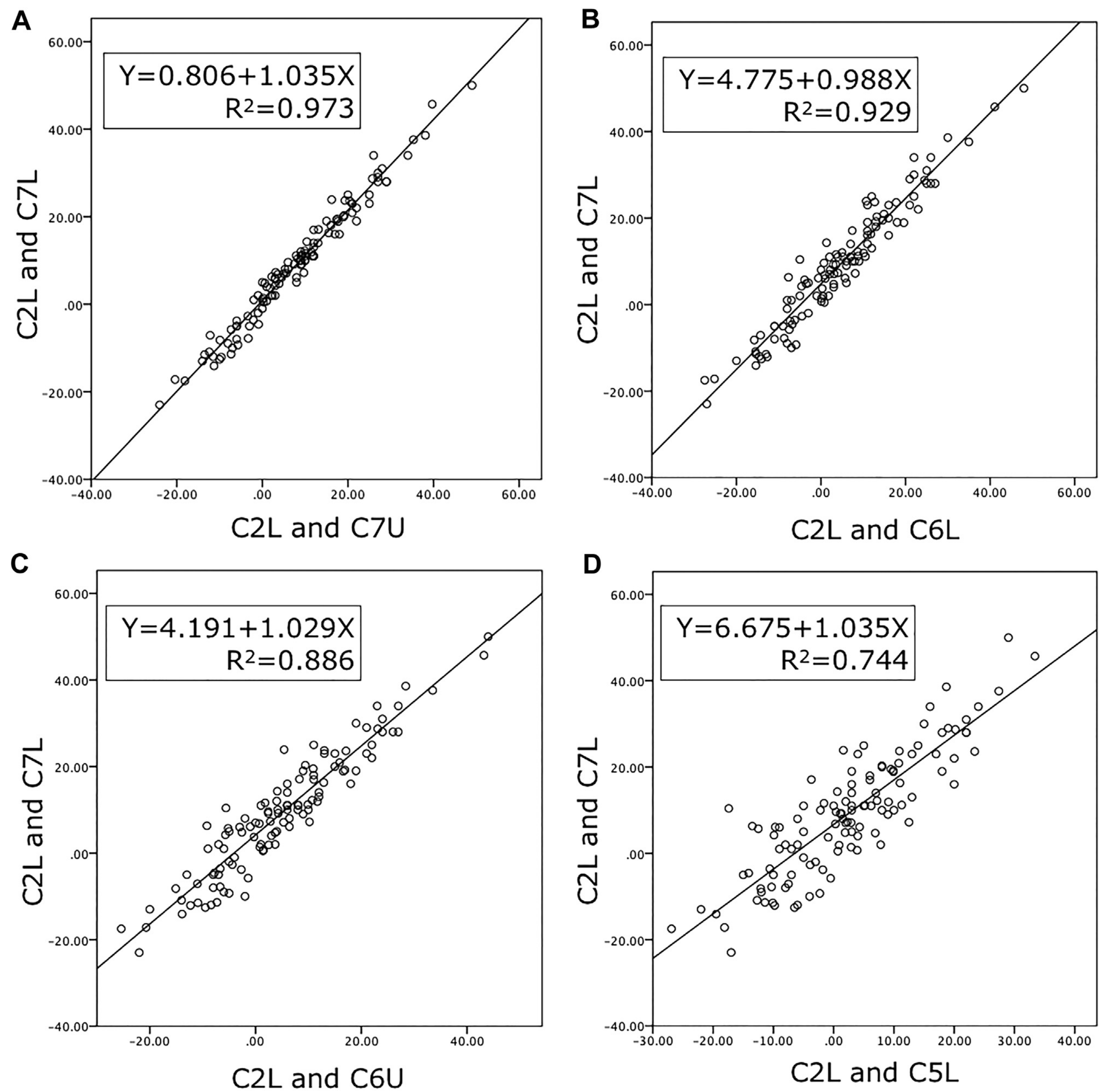

Figure 2. Linear regression analysis of the Cobb angle between the C2 lower endplate (C2L) and other endplates. (**A**) C2L-C7L angle and C2L-C7U angle, (**B**) C2L-C6L angle, (**C**) C2L-C6U angle, and (**D**) C2L-C5L angle.

Cobb angle between C2 and C7 lower endplate (C2L-C7L angle), C2 and the C7 upper endplate (C2L-C7U angle), C2 and the C6 lower endplate (C2L-C6L angle), C2 and the C6 upper endplate (C2L-C6U angle), and C2 and the C5 lower endplate (C2L-C5L angle) was measured on X-ray images (**Figure 1**).[13] Lordosis was recorded as a positive and kyphosis as a negative value. The cervical range of motion (ROM) was defined as the sum of the Cobb angle at flexion and extension on lateral radiographs.

The Cobb angle and the ROM between C2L and C7L and the other endplates were compared with the unpaired Student t test. The correlation between these angles was analyzed with the Pearson correlation coefficient (r) and linear regression analysis.

The classification of cervical alignment based on several Cobb angles and the rate of C7L visibility was assessed by χ^2 analysis. To compare findings in patients whose C7L was visible or invisible, we applied the Mann–Whitney U test and χ^2 analysis. Statistical analyses were performed using SPSS, version 24.0 (IBM Corp., Armonk, New York, USA). Differences of $P < 0.05$ were considered statistically significant.

RESULTS

Of our 191 patients, 76 (39.8%) were female; 115 (60.2%) were male. They were separated into 2 groups. In one ($n = 116$; 60.7%), C7L was identified. In the other group, composed of 75 patients (39.3%), it was not clearly visualized. In the latter without clear C7L, the lowest clearly identifiable endplate was C7U ($n = 42$, 56.0%), C6L ($n = 16$, 21.3%), C6U ($n = 14$, 18.7%), and C5L ($n = 3$, 4.0%).

As show in Table 1, C7L was visualized in 59 of 76 women (77.6%) and in 57 of 115 men (49.6%) ($P = 0.000$, χ^2 analysis), whereas the average age was not statistically significant. According to the purpose of the examination (cervical X-ray), 33 patients with cranial disease were considered to be asymptomatic and 158 with spinal disease as symptomatic. The rate of C7L visualization was significantly greater in asymptomatic than symptomatic patients ($P = 0.001$, χ^2 analysis) (Table 1).

We measured the Cobb angle only in the 116 patients (57 men, 59 women, age range 20–93 years, mean 61.1 years) whose C7L was visualized. The average C2L-C7L angle, C2L-C7U angle, C2L-C6L angle, C2L-C6U angle, and C2L-C5L angle was $9.06 \pm 1.3°$, $7.98 \pm 1.2°$, $4.34 \pm 1.27°$, $4.74 \pm 1.2°$, and $2.31 \pm 1.0°$, respectively. Except for C2L-C7U angle (unpaired Student t test, $P = 0.55$), the difference in the mean angle between C2L-C7L angle and the other parameters was statistically significant (unpaired Student t test, $P < 0.05$) (Table 2).

By using Pearson correlation analysis, we identified a very strong correlation between C2L-C7L angle and C2L-C7U angle ($r = 0.99$, $P = 0.00$), C2L-C6L angle ($r = 0.96$, $P = 0.00$), C2L-C6U angle ($r = 0.94$, $P = 0.00$), and C2L-C5L angle ($r = 0.86$, $P = 0.00$) (Table 3). Using linear regression analysis (Figure 2), we established statistically significant linear regression models by applying the following formulae: [C2L and C7L = 0.806 + (1.035 × C2L and C7U)]; [C2L and C7L = 4.775 + (0.988 × C2L and C6L)]; [C2L and C7L = 4.191 + (1.029 × C2L and C6U)]; and [C2L and C7L = 6.675 + (1.035 × C2L and C5L)].

Next, we examined the ROM by using different endplate levels. The average ROM for C2L-C7L angle, C2L-C7U angle, C2L-C6L angle, C2L-C6U angle, and C2L-C5L angle was $46.3 \pm 14°$, $45.1 \pm 14°$, $39.6 \pm 13°$, $38.1 \pm 13°$, and $31.0 \pm 10°$, respectively. As noted with respect to the Cobb angle, except for C2L-C7U angle (unpaired Student t test, $P = 0.61$), the difference in the mean between the ROM at C2L-C7L angle and the other levels was statistically significant (unpaired Student t test, $P < 0.05$) (Table 4).

The Pearson correlation was very strong between ROM at C2L-C7L angle and at C2L-C7U angle ($r = 0.98$, $P = 0.00$), at C2L-C6L angle ($r = 0.94$, $P = 0.00$), at C2L-C6U angle ($r = 0.94$, $P = 0.00$), and at C2L-C5L angle ($r = 0.86$, $P = 0.00$) (Table 5). The results of linear regression analysis of the cervical ROM are shown in Figure 3.

Table 4. Cervical ROM Using the Cobb Angle Between the C2 Lower Endplate and Other Endplates of the Lower Cervical Column

ROM	Mean ± SD (°)	*P* Value
C2L-C7L angle	46.3 ± 14	—
C2L-C7U angle	45.1 ± 14	0.61*
C2L-C6L angle	39.6 ± 13	0.002*
C2L-C6U angle	38.1 ± 13	0.000*
C2L-C5L angle	31.0 ± 10	0.000*

ROM, range of motion; SD, standard deviation; C2L, C2 lower endplate; C7L, C7 lower endplate; C7U, C7 upper endplate; C6L, C6 lower endplate; C6U, C6 upper endplate; C5L, C5 lower endplate.
*Unpaired Student *t* test compared with the value from C2L-7L angle.

Lastly, we assessed the usefulness of the Cobb angle obtained at different levels for the classification of cervical sagittal alignment. Based on the Cobb angle, we divided cervical lordosis into 3 subgroups (>+5° = lordotic, +5 to −5° = straight, <−5° = kyphotic).[18] Based on the C2L-C7L angle, 116 patients were divided into 3 groups, (lordotic [$n = 74$], straight [$n = 23$], and kyphotic [$n = 19$]) (Table 6). We also divided the 116 patients into 3 groups based on the angle at C2L-C7U angle, C2L-C6L angle, C2L-C6U angle, and C2L-C5L angle. Except for C2L-C7U angle ($P = 0.63$, χ^2 test), the difference between the angle at C2L-C7L angle and the other levels was statistically significant (χ^2 test, $P < 0.05$).

DISCUSSION

Evaluation of the cervical sagittal alignment applies parameters calculated from anatomical landmarks such as the

Table 5. Correlation Coefficients for the Cervical ROM Using the Cobb Angle Between the C2 Lower Endplate and Other Endplates of the Lower Cervical Column

ROM	C2L-C7L Angle
C2L-C7U angle	
r	0.98
P value	0.00
C2L-C6L angle	
r	0.94
P value	0.00
C2L-C6U angle	
R	0.94
P value	0.00
C2L-C5L angle	
R	0.86
P value	0.00

ROM, range of motion; C2L, C2 lower endplate; C7L, C7 lower endplate; C7U, C7 upper endplate; C6L, C6 lower endplate; C6U, C6 upper endplate; C5L, C5 lower endplate.

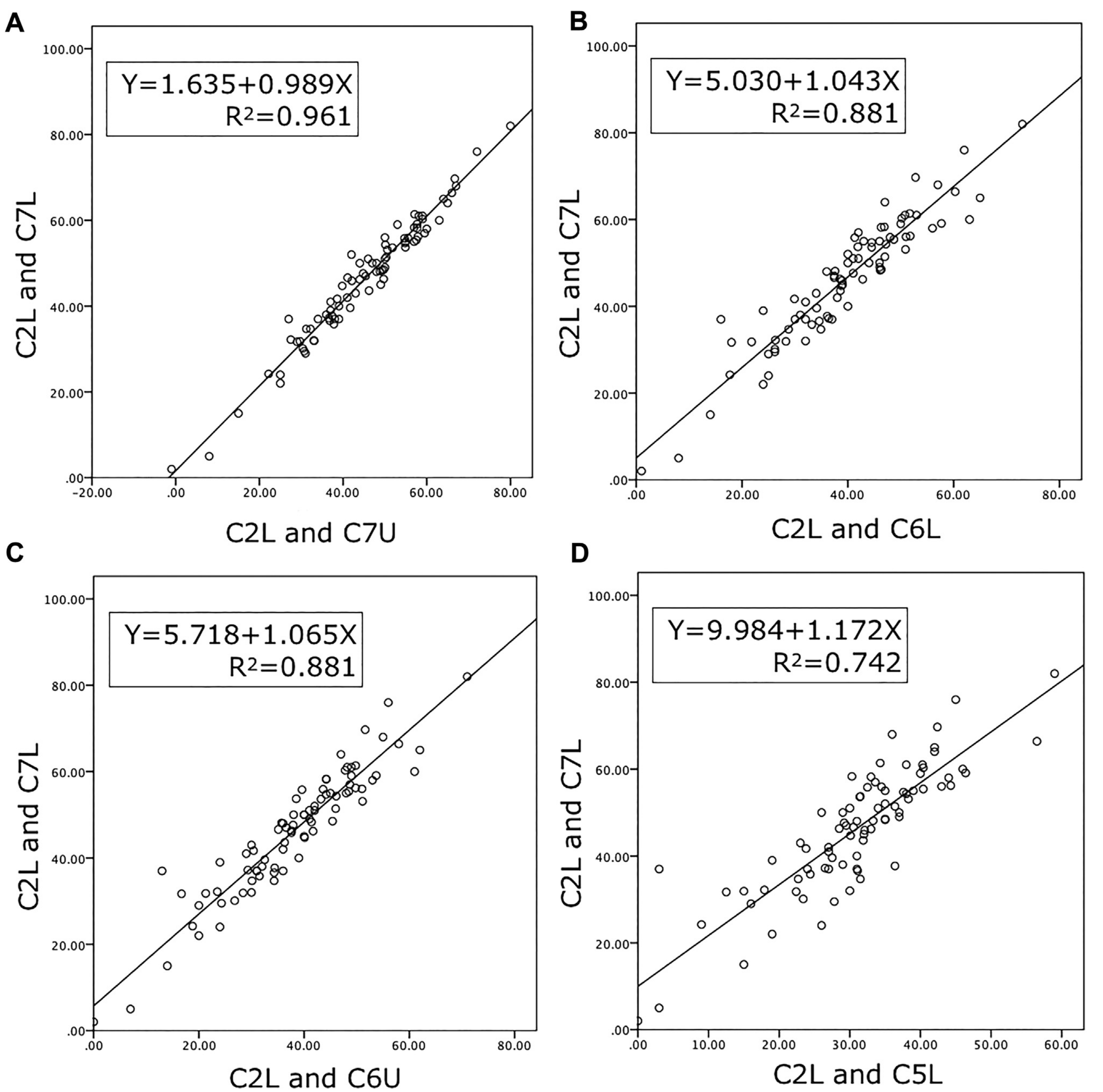

Figure 3. Linear regression analysis of the cervical range of motion based on Cobb angle between the C2 lower endplate (C2L) and other endplates. (**A**) C2L-C7L angle and C2L-C7U angle, (**B**) C2L-C6L angle, (**C**) C2L-C6U angle, and (**D**) C2L-C5L angle.

craniovertebral junction, the cervical spine, and the cervicothoracic junction.[1,7] The cervicothoracic junction is occasionally used for pre- and postoperative assessments, and the Cobb angle between C2 and the C7 lower endplate has been determined to evaluate cervical lordosis. The Gore or Jackson method also has been applied for the evaluation of cervical lordosis; they record the angle between lines drawn parallel to the posterior surface of the C2 and C7 vertebral bodies.[12] The T1 slope, defined as the angle between the horizontal plane and the T1 upper endplate, reflects the sagittal global balance.[2] The thoracic inlet angle and the neck tilt are derived from the T1 slope; they provide information on the cervical sagittal balance, e.g., the relationship among pelvic parameters, pelvic incidence, pelvic tilt, and the sacral slope.[3,17] Exact measurements of these parameters require clarity of the cervicothoracic structures on X-ray images.

Table 6. Classification of 116 Patients into 3 Groups Based on the Cobb Angle

	Alignment			
Endplate	Lordosis	Straight	Kyphosis	*P* Value
C2L-C7L angle	74	23	19	—
C2L-C7U angle	67	28	21	0.63*
C2L-C6L angle	55	32	29	0.04*
C2L-C6U angle	55	33	28	0.04*
C2L-C5L angle	45	39	28	0.002*

C2L, C2 lower endplate; C7L, C7 lower endplate; C7U, C7 upper endplate; C6L, C6 lower endplate; C6U, C6 upper endplate; C5L, C5 lower endplate.
*χ^2 test compared with the value from C2L-7L angle.

In patients with thoracolumbar spinal diseases, the sagittal vertical axis is a key factor for assessing the alignment.[1,2] Sagittal misalignment, defined as a C7 plumb line >50 mm anterior to the posterosuperior aspect of the sacrum, negatively affects the quality of life in patients with adult spinal deformity. Tang et al.,[8] who measured the C2—C7 vertical axis, demonstrated that the level of disability increased with the degree of sagittal malalignment after cervical reconstruction surgery. These findings indicate that the cervicothoracic junction is the key structure for the assessment of sagittal alignment and the global balance.

On X-ray images, the cervicothoracic junction may not be clearly depicted. Sasaki et al.,[19] who studied healthy Japanese adults, found that a shoulder shadow hampered measurements of the cervical spinal canal at the sixth and seventh cervical vertebrae. Park et al.[16] reported that the upper edge of the sternum and the T1 vertebral body were clearly visualized on only 11% of X-ray images obtained in asymptomatic individuals. We were able to identify the lower endplate of C7 in 60.7% of our 191 study subjects. Although our inclusion requirements were not strict, our findings alert to the high number of X-ray films on which the C7 vertebra was not clearly visualized.

Our findings demonstrate that 2 factors affected the visibility of the C7L on cervical X-ray films: female sex and symptoms (Table 1). Female patients are thought to have less muscle volume and lower shoulders than male patients; consequently, our findings are reasonable. Cervical degenerative changes including osteophytes and disc space narrowing tend to be observed more often in symptomatic than asymptomatic individuals. Although we found that the rate of C7L visualization was significantly greater in asymptomatic than symptomatic patients, additional studies are needed to clarify the relationship between the visibility of the lower cervical column and symptomatology by using stricter inclusion criteria.

The present study demonstrates that cervical lordosis based on C2L-C7U angle was not statistically different from the traditional Cobb angle, C2L-C7L angle (Table 2). Furthermore, there was no statistically significant difference in the ROM and the alignment classification (lordotic, straight, kyphotic) based on C2L-C7L angle or C2L-C7U angle measurements (Tables 3 and 5). These findings indicate that the C7U can be substituted for the C7L when the shoulder masks the lower cervical column. Although data obtained from C6 or C5 endplates were statistically different, the correlation between C2L-C7L angle and C2L-C6U angle, C2-C6L angle, and C2L and C5L angle was very strong (Table 3). Consequently, it is not difficult to predict cervical sagittal alignment by using the adjacent endplates on X-ray images with unclear lower vertebral bodies. To our knowledge, this is the first study to demonstrate the usefulness of the Cobb angle of adjacent endplates when C7L is not visualized on X-radiographs.

Modalities other than X-ray studies have been applied to assess cervical alignment parameters. Due to the unclearness of the X-ray films, Jun et al.[14] examined the value of the computed tomography (CT) for the assessment of cervical alignment parameters. They reported that the C27 alignment (which was same as our C2L-C7L angle) on X-ray was statistically larger than the C27 alignment on CT ($17.3 \pm 9.3°$ on X-ray, $11.35 \pm 9.3°$ on CT, $P = 0.000$) with strong correlation between the C27 alignment on X-ray and the C27 alignment on CT images ($r = 0.602$, $P = 0.000$, Pearson correlation coefficient). Liu et al.[15] found a statistically significant difference between cervical alignment values obtained by magnetic resonance imaging (MRI)-and X-ray studies ($12.89 \pm 8.38°$ vs. $16.55 \pm 8.12°$, $P = 0.000$); there was a strong correlation between the C2—C7 Cobb angle on X-ray images and MRI scans ($r = 0.699$, $P = 0.000$ [Pearson correlation coefficient]). Although CT and MRI may be alternatives to X-ray studies, measurements obtained with the subject in the supine and the erect position were very different. Therefore, we think that instead of resorting to different imaging modalities, it makes more sense to use the level adjacent to the undepicted level for assessing cervical alignment.

Our study has some limitations. First, it was retrospective and without a clinically normal population. It is possible that coexisting diseases affected the measured alignment values. Therefore, the depiction of the C7 endplate on X-ray films of healthy asymptomatic subjects must be examined. Second, all patients were Japanese and older than 20 years; it is not clear whether our findings can be extrapolated to individuals who are not Japanese. Third, all examinations were with the subjects in a sitting posture; results may differ in a standing position.[20] Nonetheless, rather than recording the absolute value of the Cobb angle at different levels, we examined whether cervical alignment could be determined based on adjacent endplate measurements. Fourth, as our study did not include adults with spinal deformity, our findings only apply in individuals whose cervical spine is aligned normally.

CONCLUSIONS

To measure Cobb angle between C2L and C7L on unclear X-ray films, C7U can be substituted for C7L. Although data obtained for C6 and C5 endplates were statistically different, the correlation between C2L-C7L angle and C2L-C6U angle, C2L-C6L angle, and C2L-C5L angle was very strong. In individuals with a normally aligned cervical spine whose lower vertebral bodies are not clearly depicted on X-ray films, the use of adjacent endplates helped to assess pre- and postoperative sagittal alignment.

ACKNOWLEDGMENTS

We thank U. Petralia for editorial assistance.

REFERENCES

1. Ames CP, Blondel B, Scheer JK, Schwab FJ, Le Huec JC, Massicotte EM, et al. Cervical radiographical alignment: comprehensive assessment techniques and potential importance in cervical myelopathy. *Spine (Phila Pa 1976)*. 2013;38:S149-S160.

2. Knott PT, Mardjetko SM, Techy F. The use of the T1 sagittal angle in predicting overall sagittal balance of the spine. *Spine J*. 2010;10:994-998.

3. Lee SH, Kim KT, Seo EM, Suk KS, Kwack YH, Son ES. The influence of thoracic inlet alignment on the craniocervical sagittal balance in asymptomatic adults. *J Spinal Disord Tech*. 2012;25:E41-E47.

4. Nunez-Pereira S, Kitzl W, Bullmann V, Meier O, Koller H. Sagittal balance of the cervical spine: an analysis of occipitocervical and spinopelvic interdependence, with C-7 slope as a marker of cervical and spinopelvic alignment. *J Neurosurg Spine*. 2015;23:16-23.

5. Oe S, Togawa D, Nakai K, Yamada T, Arima H, Banno T, et al. The influence of age and sex on cervical spinal alignment among volunteers aged over 50. *Spine (Phila Pa 1976)*. 2015;40:1487-1494.

6. Roussouly P, Pinheiro-Franco JL. Sagittal parameters of the spine: biomechanical approach. *Eur Spine J*. 2011;20(suppl 5):S578-S585.

7. Scheer JK, Tang JA, Smith JS, Acosta FL Jr, Protopsaltis TS, Blondel B, et al. Cervical spine alignment, sagittal deformity, and clinical implications. A review. *J Neurosurg Spine*. 2013;19:141-159.

8. Tang JA, Scheer JK, Smith JS, Deviren V, Bess S, Hart RA, et al. The impact of standing on regional cervical sagittal alignment on outcome in posterior cervical fusion surgery. *Neurosurgery*. 2012;71:662-669.

9. Uchida K, Nakajima H, Sato R, Yayama T, Mwaka ES, Kobayashi S, et al. Cervical spondylotic myelopathy associated with kyphosis or sagittal sigmoid alignment: outcome after anterior or posterior decompression. *J Neurosurg Spine*. 2009;11:521-528.

10. Jun HS, Kim JH, Ahn JH, Chang IB, Song JH, Kim TH, et al. T1 slope and degenerative cervical spondylolisthesis. *Spine (Phila Pa 1976)*. 2015;40:E220-E226.

11. Park MO, Moon SH, Lee HM, Kim SW, Kim TH, Lee SY, et al. The effect of age on cervical sagittal alignment. Normative data on 100 asymptomatic subjects. *Spine (Phila Pa 1976)*. 2013;38:E458-E463.

12. Silber JS, Lipetz JS, Hayes VM, Lonner BS. Measurement variability in the assessment of sagittal alignment of the cervical spine. A comparison of the Gore and Cobb methods. *J Spinal Disord Tech*. 2004;17:301-305.

13. Harrison DE, Harrison DD, Cailliet R, Troyanovich SJ, Janik TJ, Holland B. Cobb method or Harrison posterior tangent method. Which to choose for lateral cervical radiographic analysis. *Spine (Phila Pa 1976)*. 2000;25:2072-2078.

14. Jun HS, Chang IB, Song JH, Kim TH, Park MS, Kim SW, et al. Is it possible to evaluate the parameters of cervical sagittal alignment on cervical computed tomographic scans? *Spine (Phila Pa 1976)*. 2014;39:E630-E636.

15. Liu W, Fan J, Bai J, Tang P, Chen J, Juo Y, et al. Magnetic resonance imaging. A possible alternative to a standing lateral radiograph for evaluating cervical sagittal alignment in patients with cervical disc herniation? *Medicine*. 2017;96:e8194.

16. Park JH, Cho CB, Song JH, Kim SW, Ha Y, Oh JK. T1 slope and cervical sagittal alignment on cervical CT radiographs of asymptomatic persons. *J Korean Neurosurg Soc*. 2013;53:356-359.

17. Roussouly P, Pinheiro-Franco JL. Biomechanical analysis of the spino-pelvic organization and adaptation in pathology. *Eur Spine J*. 2011;20(suppl. 5):S609-S618.

18. Rajshekhar V, Arunkumar MJ, Kumar SS. Changes in cervical spine curvature after uninstrumented one- and two-level corpectomy in patients with spondylotic myelopathy. *Neurosurgery*. 2003;52:799-805.

19. Sasaki T, Kadoya S, Iizuka H. Roentgenological study of the sagittal diameter of the cervical spinal canal in normal adult Japanese. *Neurol Med Chir (Tokyo)*. 1998;38:83-89.

20. Hey HWD, Teo AQA, Tan KA, Ng LWN, Lau LL, Liu KG, et al. How the spine differs in standing and in sitting—important considerations for correction of spinal deformity. *Spine J*. 2017;17:799-806.

Conflict of interest statement: The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Received 16 May 2018; accepted 7 September 2018

Citation: World Neurosurg. (2019) 121:e147-e153.
https://doi.org/10.1016/j.wneu.2018.09.051

Journal homepage: ***www.journals.elsevier.com/world-neurosurgery***

Available online: ***www.sciencedirect.com***

1878-8750/$ - see front matter